INTERTIDAL STUDY OF THE SOUTHERN CALIFORNIA BIGHT

VOLUME II

7.0 MUSSEL COMMUNITY STUDIES

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This study was sponsored by the Bureau of Land Management,
Department of the Interior under Contract AA550-CT7-44
to Science Applications, Inc.

May 1979

ACKNOWLEDGEMENTS

This investigation was a team effort, and I wish to express my gratitude to the many people who contributed to its successful completion. Field collections were made with the help of Mike McConnell, Jack Kawashima, Fred Piltz, Richard Rowe, Mary Wright and Chris Foley. Samples were sorted by Penny Pepper, Patty Pepper, Pat Bernhardt, Chris Foley, Linda Herr and Carol Jones. Identification of mussel community inhabitants was performed by: Mary Wright (Echinodermata, Molluscs, etc. everything), Don Cadien (Molluscs), Barry Wallerstein (Isopoda and Tanaids), Dr. John Soule (Ectoprocts), Bud Wynn (Isopoda), Dr. Mary Wickcten (Crustacea), Jim Wilkins and Russel Kimble (Amphipoda), Fred Piltz, Rick Rowe, Pat Bernhardt (Polychaeta), Gene Kramer (Copepoda), Curt Smecher (Porifera), Valerie Anderson (Algae). Sediment size analysis was performed by Gigi Mohamed and Kevin Brown. I would like to express my sincere gratitude to Janet Helms for her painstaking efforts to organize the data. Also my thanks to Chris Foley and Sue Ghirardelli for their work with data and specimens. Illustrations and figures were drafted by Tom Licari and Diane Hadley. I am particularly indebted to Clyde Henry and Dr. Robert Smith for valuable assistance and companionship through the sometimes grueling data analysis period. I would also like to thank Dr. Robert Smith for his great Environmental Assessment Package (EAP) of computer programs. The analyses were performed on the University of Southern California computer facility.

The report was typed by P. Smith, P. Woodland and B. Allen.

I am particularly grateful to Dr. Dale Straughan, Principal Investigator, for her vital support, coordination efforts and most of all her continued constructive input throughout the entire project.

I wish to thank Len Cunningham, Dr. Bill Lippincott, Andy Oesterle, Rick Beauregard and others at Science Applications, Inc. for their coordinating efforts.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

7.0 MUSSEL COMMUNITY STUDIES

7.1 INTRODUCTION

The rocky intertidal region of the California coastline is characteristically banded with conspicuous zones of organisms (Ricketts *et al.*, 1968). *Mytilus californianus* (Conrad), (Mollusca:Bivalvia), dominates one of these zones in populations which are so dense that they are often referred to as "mussel beds". These mussel beds generally cover middle intertidal areas although they have been recorded as high as +1.5 m (+5.0 ft) in the intertidal zone as well as in shallow subtidal areas (Ricketts *et al.*, 1968). These limits are extremes, and the actual intertidal height of a specific population will depend on many local factors, including angle (slope) of the substrate and degree of exposure to wave action. Although *M. californianus* is the most conspicuous occupant of this region, it is not the only inhabitant.

The mussels attach to the underlying substrate and other mussels by secreting strong byssus threads. This mode of attachment enables mussels to stack up layer upon layer, often forming beds several centimeters thick. Sediment, detritus and other debris are trapped within the three-dimensional structure of the mussel bed. This material comes from a variety of sources including terrestrial run-off and suspension in seawater. The mussel bed thus becomes a microenvironment providing habitat, food and shelter for a variety of small invertebrates. This complex association of organisms is referred to as the *Mytilus californianus* community, and is named for convenience after the macroscopically dominant organism.

In the past, studies of mussel communities have been limited to selected topics such as succession (Hewatt, 1937; Reish, 1964; Paine, 1966; Cimberg, 1975). The breadth of these studies was probably limited by the complex nature of the community and by the absence of analytical techniques capable of handling the large quantity of data generated by an investigation of this elaborate community. The complexity of this community was shown in a survey of a relatively small area in central California (Kanter, 1977). A total area of less than one square meter collected by coring yielded a faunal list of over 100 species. This is, to the author's knowledge, the richest faunal concentration per unit area in the intertidal region. The extreme faunal richness and abundance were highly correlated with the three-dimensional characteristics of the mussel bed microenvironment. Specifically, the quantity of coarse-fraction material and the quantity, size and size distribution of sediment were the most important factors related to community structure. The mussel beds examined displayed considerable biotic heterogeneity. However, mussel beds separated by greater geographic distances (more than 80 km, 50 mi) were predicted to exhibit even larger community differences.

The high concentration of organisms in the mussel bed microenvironment indicates an important intertidal habitat. Any major disturbance that alters the physical or chemical nature of this microenvironment is predicted to influence the associated community. For example, oil carried ashore from an oil spill can become stranded on the mussel bed. This oil may run between the mussels and cause the death of associated fauna by smothering or acute toxic effects or both.

Investigations following major oil spills have concentrated on surface or macroscopic species (Chan, 1973; Nicholson and Cimberg, 1971; Foster et al., 1971; North et al., 1964; Straughan, pers. com.). This limited view was probably restricted by funding and time constraints. However, the fate of a major faunal component of the intertidal region, the mussel community, was consequently neglected. The Bureau of Land Management's survey of the Outer Continental Shelf affords an excellent and long overdue opportunity to document background (baseline) data on mussel communities from major geographic areas of southern California.

During the first year of this program (1975-1976), mussel communities from six geographic areas were examined. These included two mainland sites, Coal Oil Point and San Diego, and four island sites, San Miguel Island, Santa Cruz Island, Santa Barbara Island and San Nicolas Island. The faunal component of the mussel beds was quantitatively analyzed using classificatory techniques (Clifford and Stephenson, 1975). This analysis organized the large quantities of data into biologically meaningful patterns of community structure and distribution. The mussel beds sampled were divided into two distinct groups, one composed of mainland sites and the other of island sites. These two general areas were characterized by unique species assemblages. The assemblages appear to correspond with "warm" and "cold" water provinces which were previously described for intertidal species along the mainland coastline, north and south of Point Conception (Light et al., 1970; Johnson and Snook, 1967). No overall changes in species composition were noted during seasonal sampling. The mussel communities examined were very rich, encompassing conservatively 346 invertebrate species. The richest areas in terms of species diversity were Coal Oil Point and Santa Cruz Island while the lowest number of species were recorded from the San Diego and San Miguel Island mussel beds. The results suggest that oil found trapped within the mussel bed may adversely affect residents. A pilot study was initiated during the 1975-1976 program to determine if relative intertidal height of the mussel bed, within site, influenced community structure. The results of this study suggested that both species composition and abundance variations were associated with differences in intertidal height. In addition, structural features of all mussel beds including physical and chemical variates were measured during this study. Multiple discriminant analysis (Smith, 1976; Green, 1971, 1972) was used to determine which features were most consistently associated with mussel community differences. Sediment and coarse fraction (shell and rock debris) were found to be the most important structural features and provided microhabitats within the mussel bed for many invertebrate species.

The second-year (1976-1977) mussel community study was expanded to encompass a more complete geographic representation of mussel beds within the Southern California Bight. A total of eleven localities were visited including five of the original areas from the 1975-1976 program. The localities included four mainland areas, Government Point, Goleta Point, Corona del Mar and San Diego, plus seven island sites, San Miguel Island, Santa Rosa Island, Santa Cruz Island, Santa Barbara Island, Santa Catalina Island, San Nicolas Island and San Clemente Island. In addition, the intrasite sampling program was expanded to further examine the effect of intertidal height differences on community composition.

Community similarity analysis disclosed north-south distribution patterns among the mussel bed inhabitants. Many species were found exclusively or exhibited their greatest abundance in either northern or southern areas of the Bight. Other species were ubiquitous and Occurred in similar abundances among all mussel beds examined. The distribution patterns that were disclosed further refine the "warm-cold" water patterns described from the first years' limited geographic coverage (Straughan and Kanter, 1978). Additionally, the data suggest that the overall species distribution patterns are closely allied to general water circulation patterns operating in the Bight. The current and water mass movements are responsible for transporting planktonic larval recruits from source localities to distant settlement areas.

The mussel beds were quite rich, containing a total of 481 species of invertebrates and 63 species of attached algae. The most diverse communities were recorded at Santa Cruz Island and Corona del Mar which contained, respectively, 120 and 119 invertebrate species. The lowest number of species was observed at Goleta Point (57). Intrasite comparisons of samples from different intertidal heights revealed considerable biotic heterogeneity. In most cases, diversity differences existed and there was often a corresponding abundance difference within a species.

The relationship between various physical features of the mussel bed habitat and community structure were examined, as in the 1975-1976 program, employing discriminant analytical techniques. Those features associated with higher species diversity were greater quantities of coarse fraction shell and rock debris as well as qualitative differences in the trapped sediment. These findings agree with those from the first year, and the important variables were presumed to provide microhabitat resources for the associated community. Decreased community diversity was seen in mussel bed samples which contained large quantities of trapped tar and detritus.

The analysis of the first two years' data indicates that there are two categories of factors which influence community composition. These are specific local factors operating within the mussel bed habitat at a locality, and more diverse factors operating between mussel communities separated by latitudinal distances. The localized factors were measured with every mussel bed sampled. The biogeographic factors were included in the geographic sampling pattern that was established.

Communities occupying a particular locality reflect the source waters impinging on that area. Since the offshore islands are exposed to mixtures of water systems operating in the bight, it is evident that an individual collection from an island is not necessarily representative of all the mussel communities on that island.

It is not possible to sample all mussel communities within the Bight. As a consequence, one must estimate the degree of community difference and the factors which are responsible for variability in the populations that are sampled. With baseline data on the mussel community and its variation one can extrapolate to mussel beds in areas that were not sampled. This is particularly important to the BLM which must be able to generalize from the findings of this study.

The third-year program was designed to examine intra-island and annual variability in the mussel community. Sampling localities have been established on the open-ocean and mainland-facing sides of all of the channel islands except Santa Barbara Island. Additionally, the geographic coverage of mussel communities occupying mainland areas was increased to include Ventura and Carlsbad. The results of this third-year program combined with baseline and variability data from previous years should provide an adequate data base for generalizations about mussel communities in the Bight.

7.2 MATERIALS AND METHODS

This section briefly describes the methods used to sample the mussel community in the field, to conduct laboratory analysis of both biotic and abiotic components of the mussel bed and to analyze the data. A detailed methods description is included in Report III-2.0.

7.2.1 Field Sampling

The *Mytilus californianus* community was sampled at 20 rocky intertidal sites along the southern California coast (Figure II-7.0-1). The study sites included two areas on each of San Miguel, Santa Rosa,

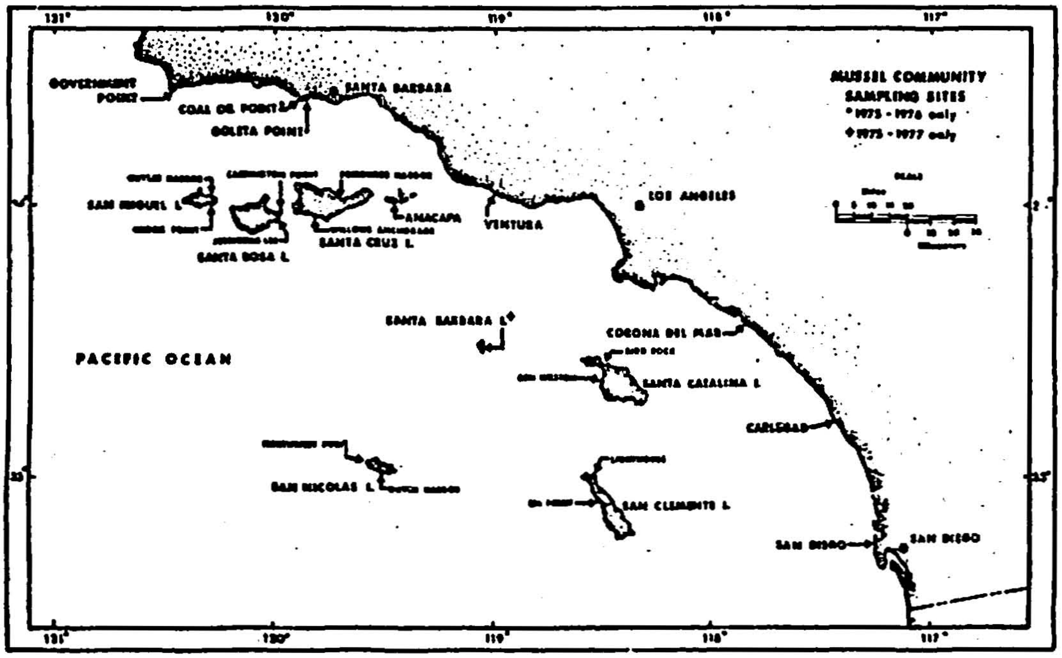

Figure II-7.0-1. Map showing mussel community collection localities. The northern arrow at Anacapa Island is the 'inner' site and the southern arrow at Anacapa Island is the 'outer' site.

Santa Cruz, Anacapa, Santa Catalina, San Nicolas, and San Clemente Islands. In addition, six mainland localities were sampled: Government Point, Goleta Point, Ventura, Corona del Mar, Carlsbad and San Diego. Table II-7.0-1 presents detailed site references to clarify all future references in the text to specific sampling sites.

Two sampling areas were established within selected collection sites at Cuyler Harbor (San Miguel Island), Eel Point (San Clemente Island) and Geoleta Point. The two areas represented the accessible, intertidal height extremes occupied by the mussel bed(s) occupied. Samples from the upper intertidal area were designated A, while those from the lower intertidal area were labelled B.

All mussel beds were sampled once on the dates listed in Table II-7.0-1. Prior to and following collection, reference pictures were taken normal to the bed surface. Field data recorded at the time of collection included air, water, internal and surface temperatures of the mussel bed environment. In addition, mussel bed thickness, aspect and intertidal height were measured. An area 1500 cm^2 was sampled by removing five 300-cm^2 cores. Each sample was collected with a stainless steel corer (Figure II-7.0-2). The core sample was removed intact, where possible, to include organisms, sediment, debris and detritus. The sample was preserved in 15% formalin and returned to the laboratory for processing of biotic and abiotic components. Each sampling area was marked for future reference with a labelled metal disk.

7.2.2 Laboratory Processing of Biota

Samples were first flushed free of formalin with fresh water. Following this, the mussels were separated from the rest of the sample. The entire sample was hand sorted separating all animals (greater than 0.5 mm) from the sediment, debris and detritus. All invertebrates and algae (attached to the mussels) were identified. The animals were counted and their abundance recorded. Algae were not quantified beyond a presence or absence record.

7.2.3 Laboratory Processing of Abiotic Components

Sediment, debris and detritus remained after the organisms were sorted out of the sample. These three components were separated and analyzed in a series of sequential operations. The sand and finer sediments were analyzed for size and size-distribution characteristics using an automatic settling tube and subsequent computer calculations (Gibbs, 1974; Cook, 1969). The coarse-fraction sediment (greater than 2 mm, mostly shell and rock debris) was analyzed for quantity, composition and pore base (interstitial space). Detrital material including algal and terrestrial plant fragments was

Table II-7.0-1. Dates of collection and specific site reference abbreviations

ISLAND COLLECTION SITES	ABBREVIATION	DATES
Outer San Miguel Island, Crook Point	SMO	October 26, 1977
Inner San Miguel Island, Cuyler Harbor	MIG	October 27, 1977
Inner Santa Rosa Island, Carrington Point	SRO	October 11 1977
Outer Santa Rosa Island, Johnsons Lee	ROS	October 12, 1977
Inner Santa Cruz Island, Prisoners Harbor	SCO	October 13, 1977
Outer Santa Cruz Island, Willows Anchorage	CRU	November 11, 1977
Outer Anacapa Island, Cat Rock	ANA	November 13, 1977
Inner Anacapa Island, French's Cove	ANI	February 23, 1978
Inner Santa Catalina Island, Bird Rock	BIR	November 25, 1977
Outer Santa Catalina Island, Ben Weston	CAO	December 13, 1977
Outer San Nicolas Island, Dutch Harbor	SNI	December 9, 1977
Inner San Nicolas Island, Northwest Point	SNO	December 8, 1977
Outer San Clemente Island, Eel Point	CLM	November 9, 1977
Inner San Clemente Island, Lighthouse Point	CLI	November 10, 1977

MAINLAND COLLECTION SITES	ABBREVIATION	DATES
Government Point	GPT	December 7, 1977
Goleta Point	GOL	October 14, 1977
Ventura	VEN	October 13, 1977
Corona del Mar	COR	December 12, 1977
Carlsbad	CAR	November 12, 1977
San Diego	SD	November 11, 1977

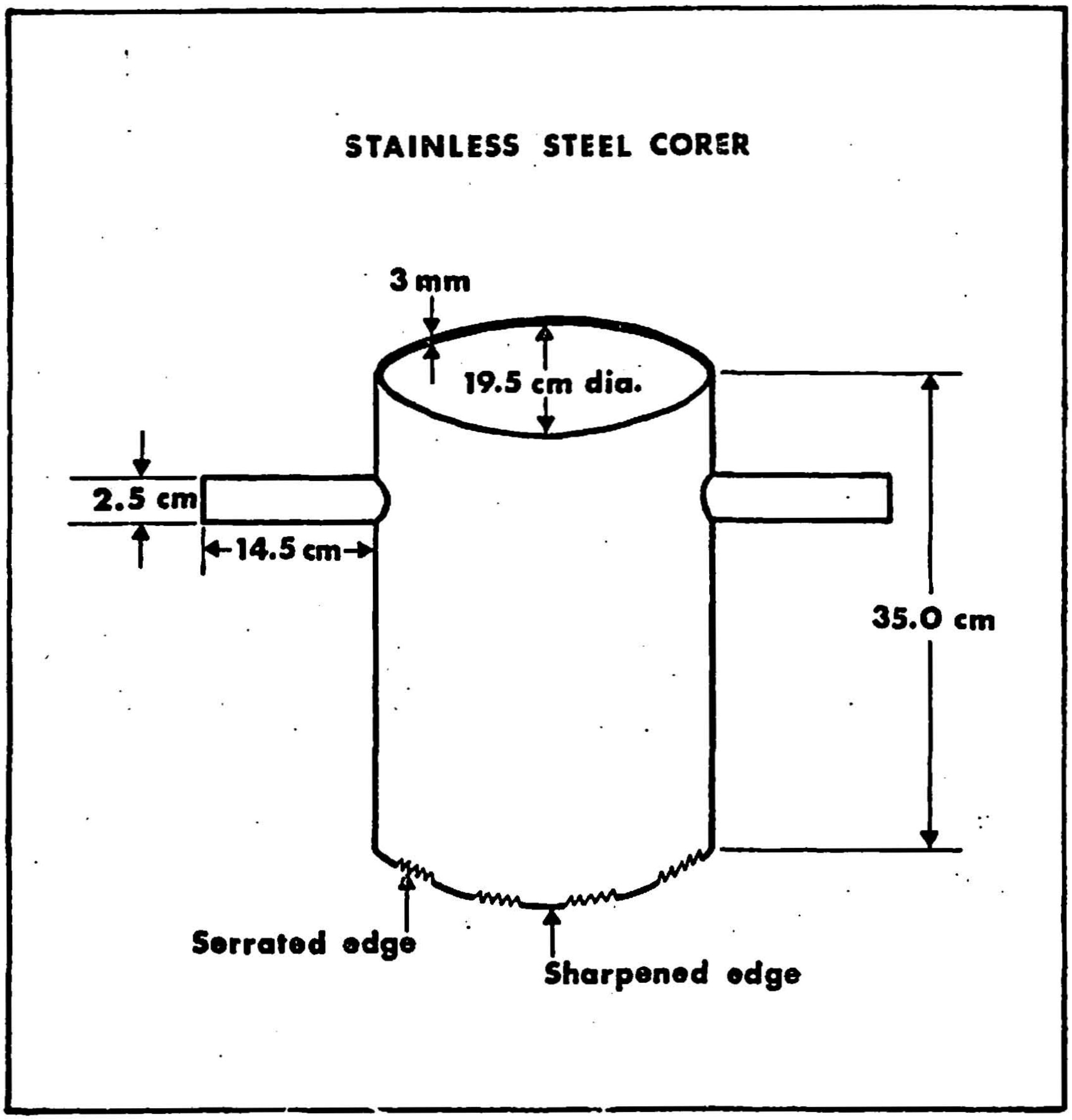

Figure II-7.0-2. Corer used for sempling.

microscopically examined then dried and weighed. Tar stranded within the mussel bed matrix was sorted out, weighed and stored for possible future chromatographic analysis.

Residual volume is the intermussel space which can be filled by associated fauna, sediment and detritus. Residual volume was calculated for each sample by subtracting the volume occupied by the mussels in a sample, from the total volume of the core sample.

7.2.4 Data Analyses

Quantitative techniques of data analysis were applied in five major areas of this study:

1. Physical characterization of mussel bed sediment based on data from automatic settling tube analysis

2. Calculation of mussel community species diversity, species richness and species eveness for each area sampled.

3. Comparison of intrasite variation in community structure with respect to samples collected from different intertidal heights.

4. Intersite comparison of Mytilus californianus communities throughout the entire Southern California Bight area under investigation.

5. Examination of the relationship between physical-chemical characteristics of the mussel bed habitat and community differences.

Sediment size and size distribution characteristics, including mean size (phi), phi kurtosis and phi skewness were calculated by computer after the formula of Inman (1952). Species diversity was calculated for each of the mussel beds sampled. Two measures of species diversity were employed, direct species counts (Pianka, 1966; Cody 1974) and the Shannon-Wiener diversity index (Pielou, 1966). In addition, species richness (Gleason, 1922) and evenness of representation in an area were calculated (Pielou, 1966).

Similarity comparisons of mussel communities both within and among geographic localities was performed using classificatory techniques (Clifford and Stephenson, 1975).

Multiple discriminant analysis was employed to determine those physical features of the mussel bed habitat most closely allied to community differences (Hope, 1969; Cooley and Lohnes, 1971; Smith, 1976). The features considered in the analysis included:

- Mussel bed thickness
- Quantity of trapped sediment
- Sediment mean size
- Sediment phi kurtosis
- Sediment phi skewness
- Quantity of shell and rock debris (coarse fraction)
- Quantity of detritus
- Quantity of tar
- Angle of the substrate
- Total residual volume
- Pore base of the coarse fraction

7.3 RESULTS AND DISCUSSION

7.3.1 Mussel Bed Community Composition

The mussel bed communities surveyed during this study supported an extremely rich assemblage of fauna and flora. The total number of invertebrate species observed was 610, representing 11 phyla (Report IV-2.0). This number should be considered a conservative estimate of the total number of species present in the mussel communities because those entities identified only to higher taxonomic levels probably include more than one species. This number of species represents a significant increase over the 481 species recorded during the 1976-1977 program and the 346 species reported in the 1975-1976 program. The increase is primarily a result of the continued expansion, both in geographic and intertidal areas sampled over the original localities visited during Year I (197 -1976). The number of species recorded from a single collection ranged from a low of 46 at Ben Weston, Santa Catalina Island to a high of 174 from Cat Rock, Anacapa Island.

As in the previous two years' programs, three phyla, the Annelida, Mollusca and Arthropoda contributed over two-thirds of all the invertebrate species. These organisms occupy a wide range of habitats within the mussel bed and exploit a variety of food resources. However, the detailed natural history of most species found in the mussel bed remains unknown and their specific food and habitat requirements can only be inferred from those of related species or morphological characteristics.

Algae attached to the surfaces of the mussels in the collections were identified, and these species are listed in Report IV-2.0. The total number of algal species recorded from all the localities was 141, amounting to greater than a twofold increase over the 63 recorded during the Year-II program (1976-1977). This increase, as with that of the fauna, is the result of the increase in geographic and intertidal areas sampled. The number of algal species recorded from a single collection ranged from a low of 1 at Dutch Harbor, San Nicolas Island to a high of 18 at both San Diego and Lighthouse Point, San Clemente Island. The most common attached algae included Gelidium sp., Ulva sp., Carpopeltis sp., Haliptylon sp., Porphyra sp., Gigartina sp., and Polysiphonia sp. These groups were represented in several of the mussel beds, and in general more species were found on island than mainland sites (Section 7.3.2).

No detrital algae were identified during Year III because of the limited information obtained from this procedure during Year II (1976-1977) (Kanter, 1978).

7.3.2 Mussel Community Diversity, Evenness, and Richness

The reports for the first two years of this study considered in some detail the relative values and usefulness of the different measures of community diversity. Table II-7.0-2 presents the data for number of species, Shannon-Weiner Diversity Index (H'), species richness (R), and evenness (J') for the five cores taken at each collecting site. Note that H', R and J' are calculated on the faunal data only, because the flora were only recorded in terms of presence/absence.

There is no apparent relationship between the numbers of floral and faunal species collected at different sites. For example, 15 algal species were recorded at outer Anacapa Island while 174 faunal species were observed in the same samples. Conversely, 23 algal species were recorded at San Diego while 120 faunal species were collected in the same samples. The number of algal species ranges from 1 to 23 from each sampling site while the number of faunal species ranges from 46 to 174.

The Shannon-Weaver diversity index (H'), evenness, and richness values also had a wide range of values at the different sites. However, the upper (A) and lower (B) intertidal sites had similar diversity-index (H'), richness, and evenness values at a given location. For example, at the Goleta Point site these values were 1.644, 0.369, and 7.759 at the upper intertidal site and 1.862, 0.422, and 7.654 at the lower intertidal site respectively.

A wide range of values were recorded at sites with and without nearby active oil seeps. Shannon-Weaver diversity index (H') values ranged from 1.517 at the San Miguel Island Inner B site to 3.482 at the

Table II-7.0-2. Diversity measures of biota at each mussel community sampling site (1977-1978).

	Number Species				
	Flora	Fauna	H'	J'	R
Government Point	12	77	2.472	0.580	7.915
Goleta Point A	22	90	1.644	0.369	7.759
Goleta Point B	11	91	1.862	0.422	7.654
Ventura	7	107	2.487	0.537	10.563
Corona del Mar	6	90	2.687	0.602	9.510
Carlsbad	13	102	2.272	0.505	9.489
San Diego	23	120	2.706	0.579	11.193
Mainland mean $\overline{X}$	13.4	96.7	2.304	0.513	9.155
San Miguel Island Outer A	12	103	1.911	0.412	9.977
San Miguel Island Outer B	14	104	1.596	0.344	9.868
San Miguel Island Inner A	7	79	1.915	0.454	7.023
San Miguel Island Inner B	9	72	1.517	0.357	6.892
Santa Rosa Island Outer	11	109	2.728	0.583	10.973
Santa Rosa Island Inner	15	120	2.615	0.550	11.722
Santa Cruz Island Outer	1	148	2.892	0.579	14.730
Santa Cruz Island Inner	17	130	3.024	0.624	12.968
Anacapa Island Outer	15	174	3.218	0.642	15.292
Anacapa Island Inner	7	79	1.867	0.430	8.491
San Nicolas Island Outer	2	101	3.426	0.745	12.194
San Nicolas Island Inner	14	130	2.613	0.560	12.102
Santa Catalina Island Outer	21	46	1.845	0.508	5.005
Santa Catalina Island Inner	16	163	3.482	0.694	16.696
San Clemente Island Outer A	4	95	2.356	0.521	10.144
San Clemente Island Outer B	10	102	2.426	0.526	11.069
San Clemente Island Inner	14	157	3.231	0.660	14.212
Island mean $\overline{X}$	11.1	112.5	2.510	0.541	11.139

Santa Catalina Island Inner site (no nearby oil seeps). However, the values for the study site at Goleta Point near active oil seeps were towards the lower end of the range (Shannon-Weaver diversity index [H'] = 1.644, 1.862).

While the full range of values for all three indices were recorded among the island sites, it should be noted that the values for the mainland sites remained in the lower part of the ranges for all three indices. The highest Shannon-Weaver diversity index (H') value among mainland sites was 2.706 at San Diego. Eight of the seventeen island sites had higher Shannon-Weaver diversity index (H') values than any of the mainland sites (Table II-7.0-2). The mean diversity index value (H') for the island sites was 2.510 while that for the mainland sites was 2.304. This pattern was also reflected on all other diversity indices on average (Table II-7.0-2). In considering whether this difference is "real" and whether it has any significance, it should be remembered that over twice as many sites were surveyed on the islands (17) as on the mainland (7). Therefore, this difference could be a result of the greater number of samples on the islands than the mainland (ranges are very sensitive to sample size), or a natural difference between the two areas, due to high population and pollution pressures on the mainland, or a combination of these elements. There is no consistent trend for higher or lower values of any of these indexes on either the outer or inner sides of the islands. While many of the low values appear in the northern section of the study area (species diversity index values range from 1.517 to 1.915 at San Miguel Island and 2.426 to 3.231 at San Clemente Island), there is considerable overlap. This is considered later in the discussion of discriminant analysis (Section 7.3.5).

Comparison of the number of faunal species recorded at localities surveyed during the three-year period shows a general increase in species numbers between Years I and II while in Year III values continued to increase at some sites, remain stable at other sites, and decrease at still other sites (Table II-7.0-3). The changes in species number may be influenced by many factors including yearly recruitment, larval survivorship and microhabitat features (Section 7.2.5).

7.3.3 Community Differences Associated with Upper and Lower Intertidal Collections

The effect of intertidal height differences on intrasite community composition was investigated at four collection localities including one mainland locality, Goleta Point, and three island localities, Cuyler Harbor and Crooks Point on San Miguel Island and Eel Point, San Clemente Island. Classification analysis, involving the calculation of intersample similarity based on species composition and abundance was employed. Hierarchical dendrograms were constructed to display similarity between samples. Each dendrogram

Table II-7.0-3. Number of faunal species recorded during the three years of study.

Year	75-76				76-77		77-78
	Su	F	W	Sp	Su	W	Su
Government Point					45,100	57,59	77
Coal Oil Point	70		75				
Goleta Point					62,53	48,63	90,91
Corona del Mar					107,131		90
San Diego	48		43		63,75		120
San Miguel Island Inner		41	55	51,55	85,93		72,79
Santa Cruz Island Outer	74	78	69	75	113,126		148
San Nicolas Island Outer	49	53	53	63	79,100		101

Su = Summer, F = Fall, W = Winter, Sp = Spring. Two numbers indicate values for different intertidal levels.

figure contains a relative scale of similarity ranging from 0 to 200, with decreasing similarity corresponding to higher values. The similarity between elements is obtained by relating the vertical dendrogram lines connecting entities to the similarity scale on the figure. At each site, samples labelled A were collected from higher intertidal levels than samples labelled B.

The classification results for the samples collected from Goleta Point (GOL) are displayed in Figure II-7.0-3. The dendrogram exhibits a well defined split separating A and B samples at the 72 level. This level of similarity was identical to that observed in collections from the summer Year-II (1976-1977) sampling program.

The classification results for the samples collected from upper and lower intertidal areas on both sides of San Miguel Island (SMO and MIG) also display clear dendrogram splits (Figure II-7.0-4 and II-7.0-5). The upper and lower samples are separated at the 62 and 80 levels of similarity for Crooks Point and Cuyler Harbor collections, respectively. The Cuyler Harbor mussel community samples from upper and lower intertidal areas collected during Year II (1976-1977) displayed the same degree of dissimilarity as the Year-III samples.

The San Clemente Island (Eel Point) samples from upper and lower intertidal areas did not show clear differences. The classification of samples resulted in the formation of three separate clusters of samples (Figure II-7.0-6). Group one includes samples 2, 3, 4 and 5A. Group two contains samples 1A and, 2 and 4B. Samples 1, 3 and 5B form group 3. The mixture of A and B samples in group 2, combined with the greater affinity of group 2 to group 1 than group 3, suggests that considerable heterogeneity exists among the samples collected from this locality. The Year-II collections from upper and lower intertidal heights displayed the same heterogeneity as the Year III samples.

The dendrograms from Goleta Point and both sides of San Miguel Island (Figures II-7.0-3 through II-7.0-5) all contained primary splits which clearly separated upper and lower collections suggesting community differences. This separation indicates that the upper samples were distinctly different from the lower samples and that both groups exhibited close internal consistency. The dissimilarity between collections resulted from variations in the species composition and relative abundance. However, it should be noted that the species diversity (species counts) values exhibited by the three localities with dissimilar A and B samples were very close (Table II-7.0-4) a difference of one species separated the upper and lower mussel beds for samples from Goleta Point and Cuyler Harbor, San Miguel Island. Therefore, relative abundance appears to be the more important factor. Another interesting feature is that collections made from upper and lower intertidal areas during Year II (1976-1977) from the same locality displayed the same degree of dissimilarity as

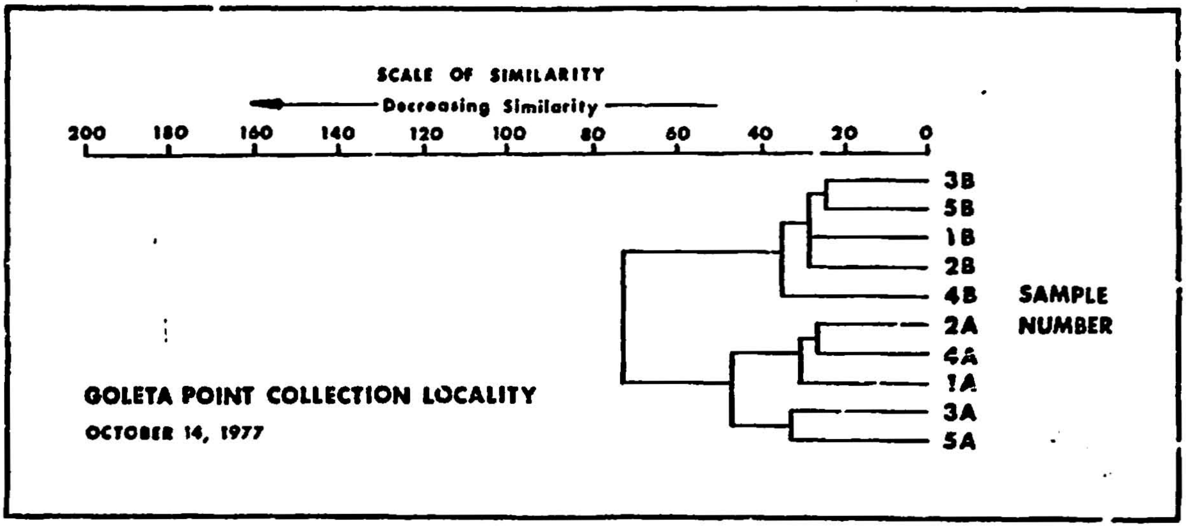

Figure II-7.0-3. Dendrogram from intertidal height comparison of Goleta Point samples.

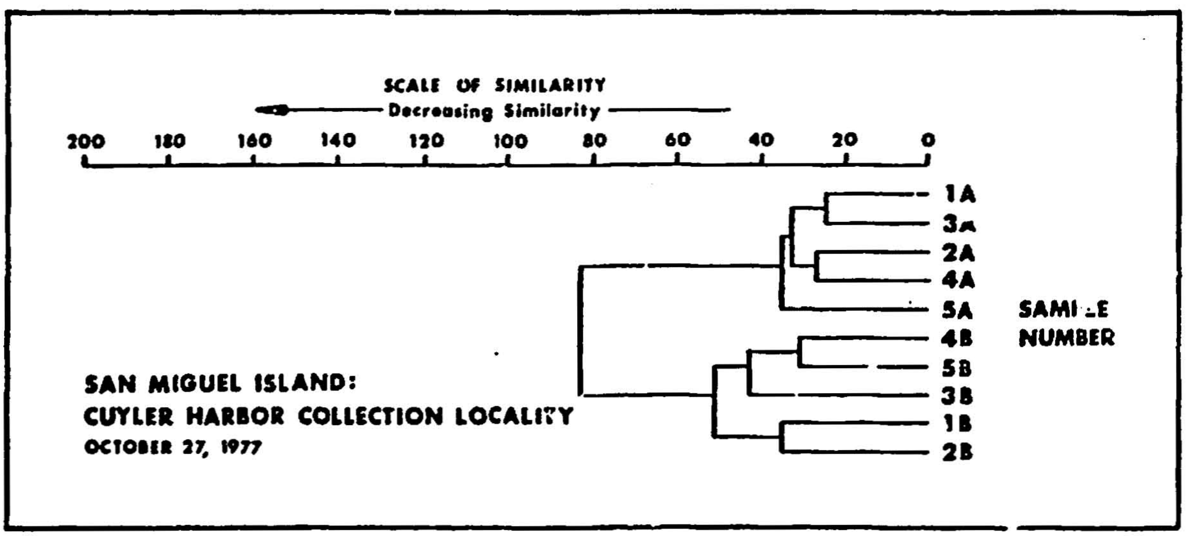

Figure II-7.0-4. Dendrogram from intertidal height comparison of Cuyler Harbor, San Miguel Island samples.

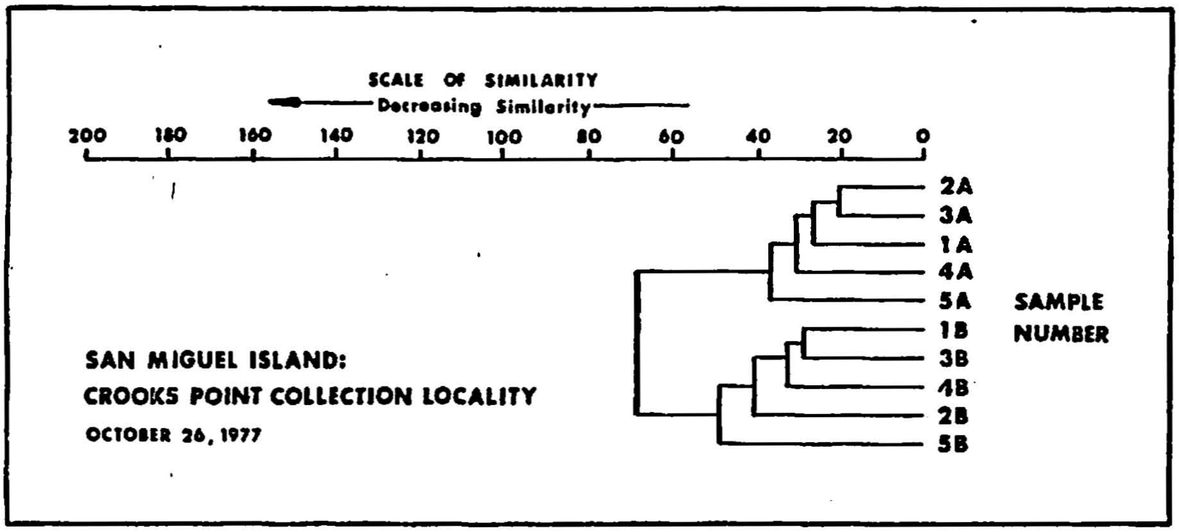

Figure II-7.0-5. Dendrogram from intertidal height comparison of Crooks Point, San Miguel Island samples.

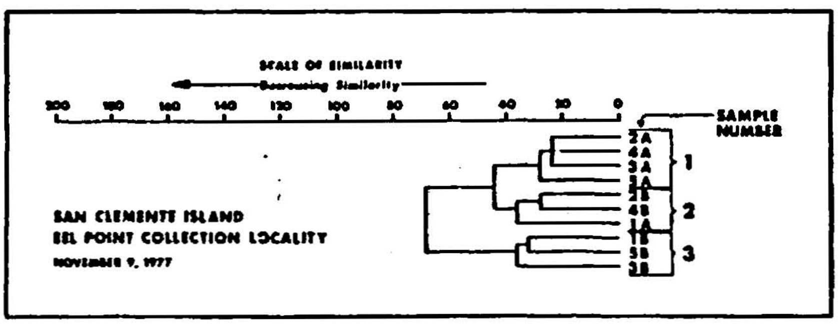

Figure II-7.0-6. Dendrogram from intertidal height comparison of Eel Point, San Clemente Island samples.

Table II-7.0-4. The differences between upper and lower intertidal height and species diversity differences.

Locality	Collection	Number of Species	Differences in Intertidal Height
Goleta Point	A	90	1.45 m
	B	91	(4.73 ft)
Cuyler Harbor, San Miguel Is.	A	79	2.41 m
	B	72	(7.89 ft)
Crooks Point, San Miguel Is.	A	103	0.03 m
	B	104	(0.11 ft)
Eel Point, San Clemente Is.	A	95	0.33 m
	B	102	(1.05 ft)

the collections from Year III. These results suggest that there has been little relative change in the number of species between upper and lower intertidal levels.

Several mussel beds displayed community differences associated with upper and lower intertidal areas. Although upper and lower bed community composition was different, the number of species was often similar (Table II-7.0-4). The obvious dissimilarity between the communities at the two intertidal levels suggests that factors associated with these extremes are influencing the biota. Two basic groups of factors exist, physical and biological. Biological interactions include predation or competition by species for limited resources (Connell, 1961; Dayton, 1971). The physical factors include those microenvironmental variables considered in the multiple discriminant analysis section (7.3.5) as well as some which are more directly associated with tidal exposure regimes. Areas which are higher in the intertidal zone are exposed for longer periods of the tidal cycle than those areas immediately below them in intertidal height. This means that exposure time to aerial temperatures and desiccation are longer in upper intertidal areas. Mussel beds provide excellent insulation by maintaining internal temperatures below ambient air temperatures (Figures II-7.0-7, II-7.0-8). However, other factors such as elevated mussel bed surface temperatures, or occasional fresh water influx may limit species distributions in the mussel bed. These factors combined with physiological limits in tolerance to aerial exposure time and the potential of desiccation probably control the species inhabiting upper and lower intertidal areas of the mussel bed. Since the mussel bed samples from upper and lower intertidal areas represent the extremes at a particular area, it is suggested that middle intertidal areas between extremes will reflect a "blend" of the entire community and will probably harbor representatives of the bulk of the species complement inhabiting a specific geographic locality.

7.3.4 Mussel Community Similarity Analysis Between Localities

Intercommunity similarity analyses were performed using classificatory techniques. The analyses produced normal (site) and inverse (species) dendrograms which were then arranged in a two-way coincidence table. The normal dendrogram contains clusters of localities based on similarity of faunal composition. The inverse dendrogram contains clusters of species with similar distribution patterns among localities. The two-way coincidence table combines the normal and inverse analyses into a form which summarizes the results. The cells of the two-way table characterize the site groups with respect to faunal composition and abundance and contain symbols representing relative abundances based on the maximum abundance for each species.

The site groups which result from the normal analysis are labelled with arabic numerals for easy reference in subsequent discussions of the similarity analysis (Figure II-7.0-9). Species groups are

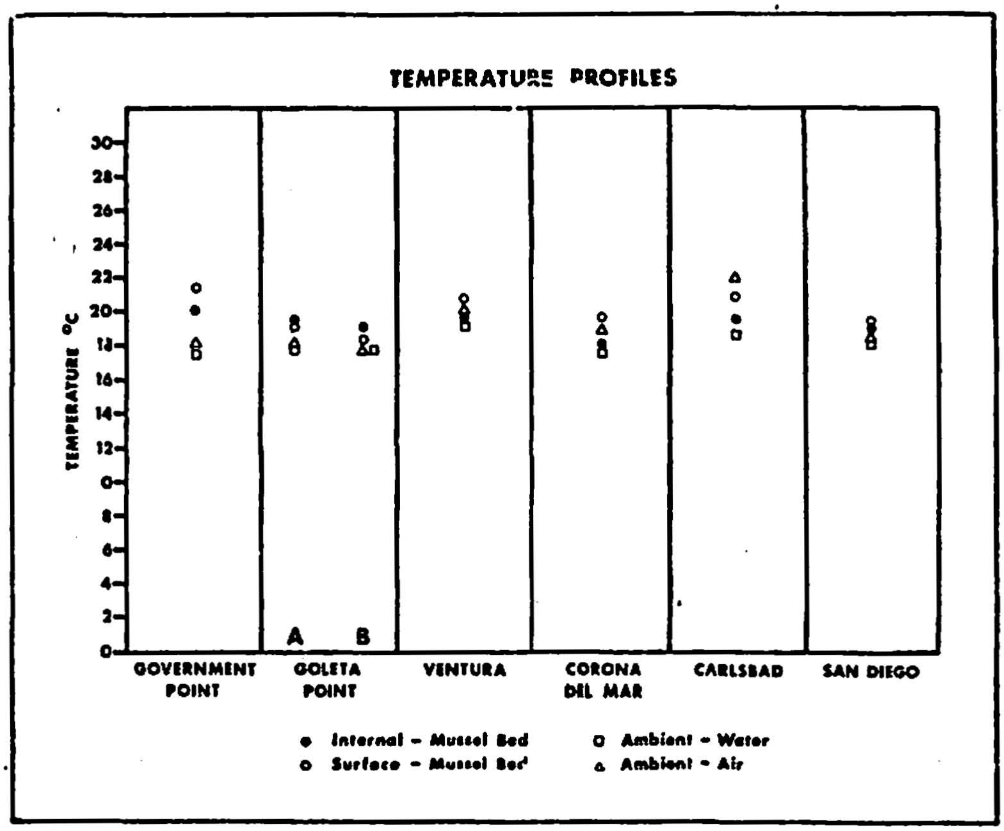

Figure II-7.0-7. Temperature profiles for mussel bed collections, at mainland sites.

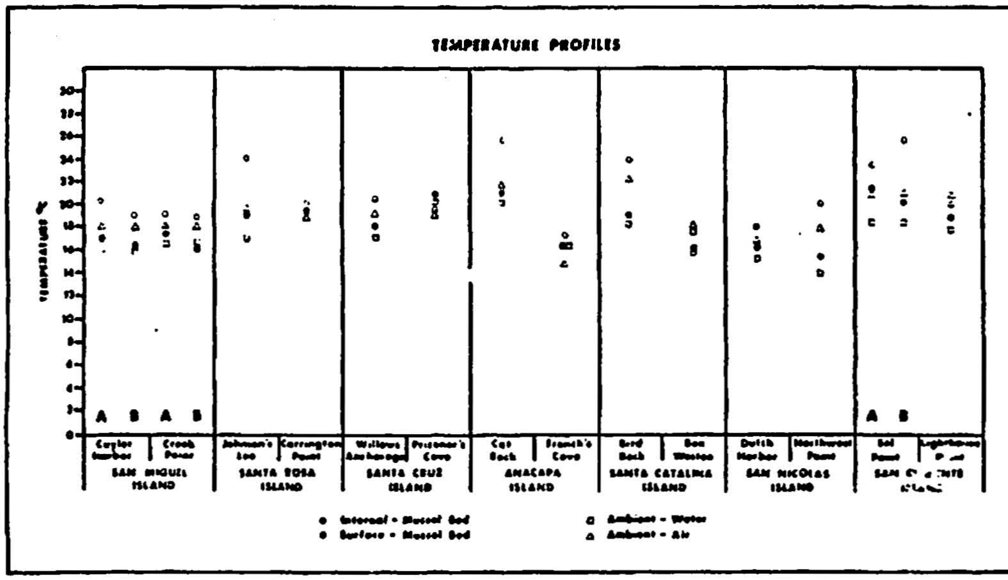

Figure II-7.0-8. Temperature profiles for mussel bed collections at island sites.

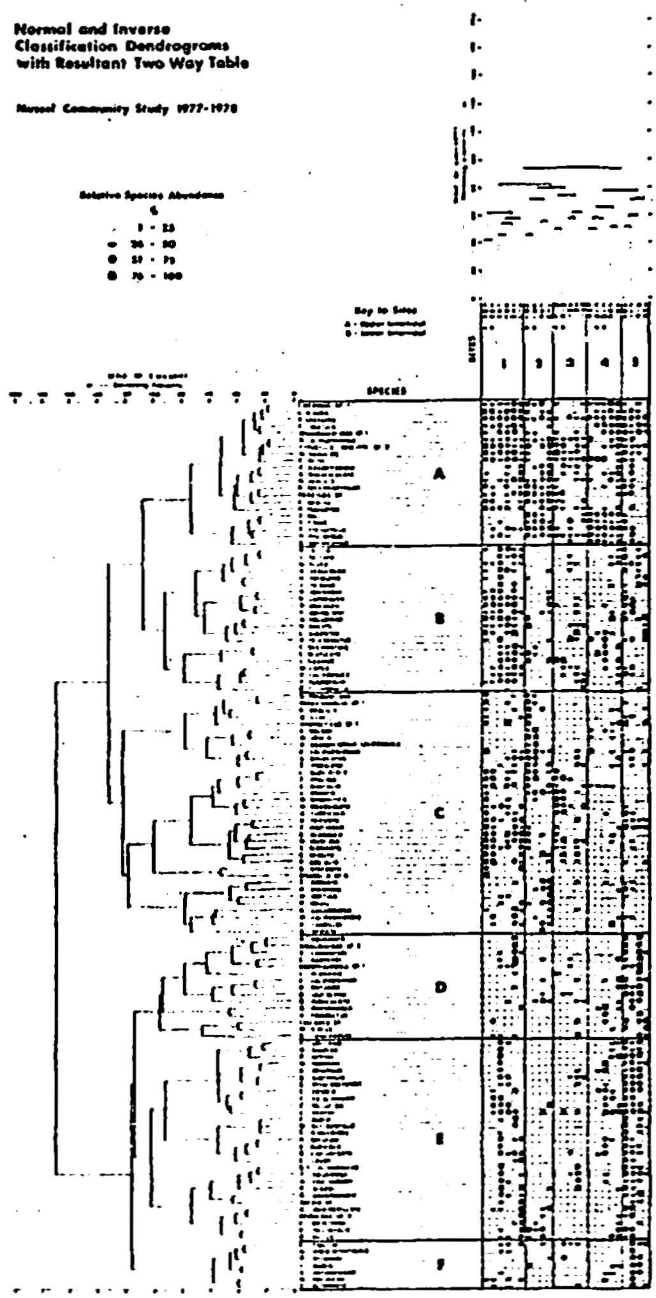

Figure II-7.0-9. Normal and inverse classification dendrograms with resultant two-way table.

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similarly labelled with capital arabic letters for reference. In order to interpret the species composition of a specific group, it is necessary to refer directly to the two-way table (Figure II-7.0-9). The phylum of a particular species can be found in Report IV-2.0.

The analysis revealed five major patterns which corresponded to characteristic species assemblages occupying the mussel beds of various geographic areas (Figure II-7.0-9). Although each of the patterns is distinct, the relative placement of a study site or species in a specific group is probably the result of a combination of several underlying phenomena. The observed patterns are: (1) clusters of study sites which display a north-south geographic pattern with respect to the similarity of their respective mussel communities, (2) a separation of selected island and mainland communities because of dissimilarities in their species composition, (3) differences between mussel communities on opposite sides of the offshore islands, (4) clusters of species whose highest abundances characterize particular study sites, (5) species groups ubiquitous to all mussel beds examined.

The overall normal classification, which includes sites with upper and lower intertidal collections, shows one primary and three secondary divisions on the dendrogram resulting in five clusters of sites.

The primary dendrogram division separates site groups 1, 2 and 3 from site groups 4 and 5. Secondary dendrogram divisions in turn separate site groups 1, 2 and 3 from each other and site groups 4 and 5 from each other (Figure II-7.0-9). Site group 1 is composed of northern island localities including the upper and lower intertidal collections from Crooks Point, San Miguel Island (SMO), both sampling areas on Santa Rosa Island (SRO, ROS) and both sampling areas on Santa Cruz Island (SCO, CRU). Site group 2 contains mainland collection areas from Goleta Point, both upper and lower intertidal samples (GOL A, GOL B), and collections from Ventura (VEN) and Carlsbad (CAR). Site group 3 is composed of northern island collections from Cuyler Harbor, San Miguel Island (upper and lower intertidal MIG A and MIG B), French's Cove, Anacapa Island (ANI), a more southern island area at Dutch Harbor, San Nicolas Island (SNI) and the northernmost mainland site, Government Point (GPT). Site groups 4 and 5 contain mixtures of southern island and mainland collection localities. Site group 4 contains the Ben Weston, Santa Catalina Island collections area (CAO), the upper and lower intertidal sampling areas at Eel Point, San Clemente Island (CLM A, CLM B), the Corona del Mar locality (COR) and the San Diego collection area (SD). Site group 5 contains one of the more northern collection areas, Cat Rock, Anacapa Island (ANA). However, this study site faces the remainder of the southerly collection sites. Also included in site group 5 are collection sites at the northwest point of San Nicolas Island (SNO), Lighthouse Point, San Clemente Island (CLI), and the Bird Rock site on Santa Catalina Island (BIR).

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The results of the Year-II BLM study (Kanter, 1978) suggested a north-south biogeographic pattern in the similarities between mussel communities collected from various areas in the Southern California Bight. This original suggestion is reinforced by the results from the Year-III (1977-1978) study. The increased geographic coverage provided by the addition of sampling areas not previously visited, significantly increased the definition of the north-south pattern. The primary dendrogram split clearly separates the "northern" collection areas, site groups 1, 2 and 3, from the "southern" collection areas, site groups 4 and 5. Remembering that clustering of collection sites implies that the mussel communities sampled in these areas are more similar in their species composition and relative abundance to each other than to communities outside the cluster, we can elaborate on the resultant biogeographic patterns.

The Year-I and Year-II (Straughan and Kanter, 1978; Kanter, 1978) BLM mussel community studies provided data indicating that two distinct faunal provinces had been sampled. Further, these provinces corresponded to the "warm-water" and "cold-water" assemblages previously described as occurring north and south of Point Conception, California (Johnson and Snook, 1967; Light et al., 1970). In addition, the results suggested that the "cold-water" provinces should extend south of Point Conception if one considers the mussel community inhabitants when discussing this phenomenon. This same pattern is clearly exhibited in the Year-III results by the clustering and close similarity displayed among northern Channel Island and mainland communities. There are within the "northern" site groupings additional patterns. Site group 1, for example, is composed entirely of island collection areas from the northernmost localities, whereas site group 2 is composed almost exclusively of northern mainland localities (with the exception of CAR). Site group 3 contains a notable mixture of study areas. The northernmost mainland collection area at Government Point is very similar to the northern channel island site at San Miguel, the north-facing site on Anacapa Island (ANI) and the Dutch Harbor (outside) collection area on San Nicolas Island (SNI). This interesting arrangement is best explained by considering the impinging water regimes in the areas as discussed later.

The "southern" localities are also clustered according to the similarities of their respective mussel communities. Site group 5 is composed exclusively of southern island localities, whereas site group 4 contains a mixture of mainland and island sites. The inclusion of the Anacapa Island, Cat Rock (ANA) locality in site group 5 is notable. This area faces due south and is probably the recipient of waters of similar hydrographic characteristics to those impinging on many of the more southerly localities.

Prior to the Year-III mussel community study, one collection area was established on many of the offshore islands. Unfortunately, a single collection area cannot be assumed to be representative of an entire island. This is particularly true considering the heterogeneity of water regimes surrounding the islands both in physical-chemical terms and with respect to biotic composition (e.g. plankton). The establishment of multiple sampling localities on opposite sides of the offshore islands during Year III significantly increased our knowledge of island mussel communities. The normal dendrogram results illustrate distinct dissimilarities between many of the pairs of collections from the same island (Figure II-7.0-9). The most dramatic differences are displayed by the collections from San Nicolas Island and Anacapa Islands. The SNI and ANI collections occur in site group 3 and these cluster with the "northern" study sites, illustrating that the SNI and ANI mussel communities resemble the "northern" mussel communities more than their intra-island counterparts. Conversely, the SNO and ANA sites contain communities which more closely resemble the mussel beds found at the "southern" collection areas. Less dramatic but still significant differences are evident in the communities from opposite sides of San Miguel Island and San Clemente Island. Although each study site maintains fidelity to its overall "northern" or "southern" geographic group, significant faunal differences exist which place SMO and MIG separately in site groups 1 and 3, respectively, and which place CLM and CLI in site groups 4 and 5, respectively.

Most of the mussel community inhabitants reproduce by releasing gametes into the surrounding waters where external fertilization and development of larvae occurs. Species which do not undergo external fertilization may also release their developing larvae into surrounding waters. The result is that planktonic larvae entrained in offshore waters drift with prevailing currents and water masses. Drifting terminates when the larva has matured enough to actively seek out an appropriate habitat with an environmental regime that falls within its physiological tolerance range. This phenomenon of planktonic recruitment from distant source areas allows not only the mapping of prevailing current and water mass regimes by tracing probable pathways of water movement, but also predictions of which inhabitants are likely to occur in neighboring areas which were not specifically sampled. A very generalized diagram of water circulation patterns occurring in the southern California area is presented in Figure II-7.0-10. This figure depicts primarily net surface water circulation based on oceanographic observations using several techniques including current meters, weighted and unweighted drift cards and other hydrographic data. The diagram does not depict subsurface current, localized gyre or seasonal anomalies which are known to exist. The patterns illustrated suggest that "cold water" arising north of Point Conception flows southerly and swings offshore impinging on the offshore islands as it continues its southward movement. In addition, a northerly movement of "warm water" arising in more tropical areas flows northward along the mainland coast.

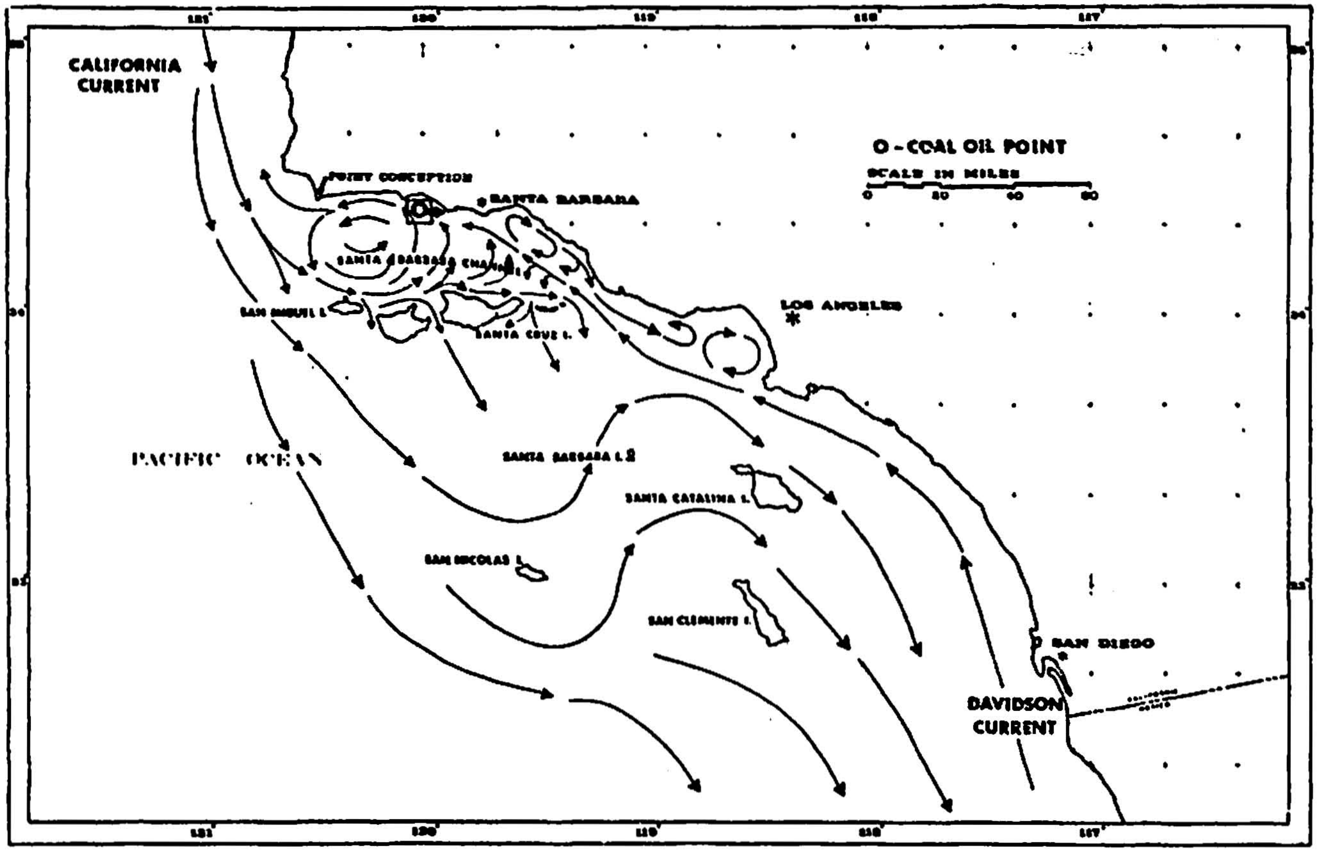

Figure II-7.0-10. Generalized ocean circulation pattern in southern California study area.

Larval recruits are presumably carried by these two primary water sources to settlement areas. In the Year II report (Kanter, 1978) the circulation pattern illustrated by Figure II-7.0-10 was modified to take into account the biological information consisting of similarities between mussel communities at the various sites. The assumption is that areas with similar communities receive planktonic larval recruits from similar source waters (source parental stock). This assumption serves as a basis for delineating the biogeographical extent of similar communities by extrapolation from observed biological distribution patterns. Figure II-7.0-10 has been further refined with the inclusion of community similarity information from Year III (Figure II-7.0-11). The hypothesized circulation patterns generally account for some of the gross community differences between "northern" "cold water" assemblages. Figure II-7.0-11 represents at best a generalization of the water-movement regime in the study area, but does agree with empirical data presented by Bernstein et al. (1977). However, the true patterns are likely to be much more complex once fully described. The water-regime features which contribute to the gross community differences are factors which act differentially between the various geographic sampling locations and as a result are considered biogeographic variables. In addition to biogeographic variables which affect community composition, site-specific variables influence the community make-up. These variables are much more localized in their effect and include species interactions (e.g. competition and predation) and abiotic factors which govern the microenvironmental habitat features. Biologic interactions were not examined in this study. However, the abiotic habitat features were and are discussed in Section 7.3.5 (Discriminant Analysis of Mussel Bed Abiotic Characteristics).

The inverse analysis yielded six species groups labelled A through E. Species group A is a ubiquitous assemblage of organisms found in practically all the mussel beds sampled. The overall abundances of the species in this group were slightly higher in collections from site groups 1, 2 and 3 than in collections from the other site groups. Species group A was very similar in composition to the ubiquitous species groups from Year I and Year II (Straughan and Kanter, 1978; Kanter, 1978). The group included several species of limpets, Collisella scabra, C. limatula, C. pelta, and C. strigatella, the nemerteans Emplectonema gracile and Paranemertes peregrina, the crab Pachygrapsus crassipes, the barnacles Chthamalus fissus and C. dalli, the polychaetes Typosyllis fasciata sp. D and Arabella semimaculata, and the sea anemone Anthopleura elegantissima. Additional ubiquitous species were scattered among the other species groups including groups C and E. This was primarily a result of their relative abundance distributions among the sites. Included in this list of species were the molluscs Septifer bifurcatus and Lasaea subviridis, the polychaete Naineris dendritica and the barnacles Tetraclita squamosa and Balanus glandula.

Species in group B characterized those study areas in site group 1. Most of the species occurred in their highest relative abundances at the sites in group 1. Generally, these species occurred at sites in

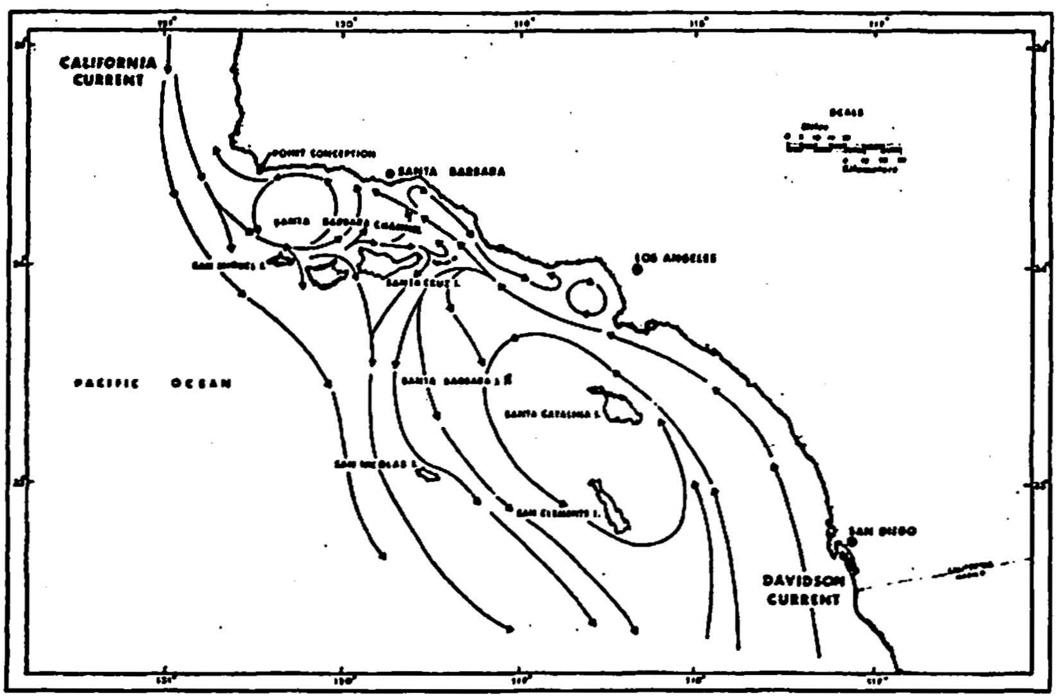

Figure II-7.0-11. Circulation pattern in study area based on mussel community classification dendrograms with resultant two-way table.

other groups but in low or very low abundances. Among the distinctive species in this group was the peanut worm Phascolosoma agassizii and the bivalve mollusc Kellia laperousii.

Site groups 1 and 2 were characterized by high relative abundances of several members of species groups B and C. Site groups 3 and 4 were characterized by relatively low abundances of species in most species groups. With the exception of some ubiquitous species of group A, including the limpets Collisella pelta, C. strigatella and the barnacle Pollicipes polymerus, very few species displayed their maximum abundance at these localities.

Many of these species also occurred at other localities. However, their relative abundances were much lower. Species such as the chiton Cyanoplax hartwegii occurred in all mussel beds from site-group 1 areas in high relative abundances but were not found in these frequencies in any other sites.

Species groups D, E and F characterized site group 5 in terms of high frequency and abundance. Few members of these species groups were found in mussel beds collected at the study areas comprising site groups 2, 3 and 4. However, several of the species from species groups D, E and F were encountered in collections from site group 1. Although in relatively low abundances, species such as the bivalve Philobrya setosa and the gastropod Ceritniopsis cosmia were found in very high abundances among areas from site group 5 and in practically no other mussel beds.

Species from species group F, although present in some abundance at most sites are notably absent from the mussel beds from site-group 2 areas.

Practical limits imposed by funding, time and impacts to biologic communities preclude sampling and describing every mussel community in the Southern California Bight. The third-year sampling regime represents the most complete mussel community study to date. The combination of these results with data from the Year-I and Year-II programs provides a comprehensive baseline species list for mussel communities in the Bight. The community-similarity information classified study sites with comparable biota and thus provides a basis for predicting community composition in areas not specifically sampled. With knowledge of the geographic location and proximity to the beds characterized by this study, the composition of mussel communities from neighboring areas can be predicted with a high degree of confidence.

7.3.5 Discriminant Analysis of Mussel Bed Abiotic Characteristics

The mussel community differences described in Section 7.3.4 are controlled by two general categories of variables. These include between-habitat variables which were described previously.

Within-habitat features operate at each specific geographic area. These features include the abiotic characteristics measured within the mussel bed.

Multiple discriminant analysis was employed to identify the most important abiotic features associated with mussel community differences. Eleven mussel bed abiotic factors were measured during this study (Section 7.2). During Year II (1976-1977), two additional variables were measured that were not considered in the program design this year, organic carbon content of the trapped sediment and absolute intertidal height of the mussel bed. Organic carbon content of trapped sediments examined during Years I and II was very low and was not among the dominant physical factors. The absolute intertidal height during previous years was determined by relating mussel community sampling areas to bench marks established by Dr. Littler. This was impossible during Year III because the additional sampling sites did not always correspond to areas sampled by Dr. Littler, nor were they close to any U.S. Coast and Geodetic Survey (USCGS) benchmarks. As a result, tidal heights in most cases were estimated from the time of low tide and prevailing water level. These relative heights were not considered accurate enough to include in the calculations. It should be noted, however, that the effect of intertidal height (in the Year-II discriminant analysis studies) was insignificant compared to other habitat variables in accounting for intercommunity differences and therefore the omission of this variable should not affect the current results.

The variables considered in the discriminant analysis provide separately or in combination food, habitat and shelter resources for mussel community inhabitants. Some variables may alone provide combinations of resources for selected species. For example, sediment creates both habitat and food for deposit feeding polychaetes. Discriminant analysis produced linear combinations of variables which best separated predefined groups from the classificatory analysis. The relative importance of a variable in the construction of a discriminant axis was indicated by the magnitude of its respective coefficient of separate determination. These coefficients are presented in Table II-7.0-5; those of the most important variables are indicated on the discriminant axes (Figure II-7.0-12). The group means for each variable considered are listed in Table II-7.0-6. The cumulative percentage of variance accounting for group separations by each axis is also tabulated (Table II-7.0-7). The vector diagram in Figure II-7.0-12 indicates the direction of increase of group means for the important abiotic variables. The direction of increased species diversity is also indicated on this figure. The important variables are interpreted in relation to the overall community structure and diversity differences. Interpretation of important variables in relation to particular species requires individual consideration of the species and its detailed natural history. This was not attempted in this study.

Table II-7.0-5. Coefficients of separate determination for the overall discriminant analysis. (The magnitude of those elements underlined indicates their relative importance in the formation of the discriminant axes.)

ABIOTIC CHARACTERISTIC	AXIS 1	AXIS 2	AXIS 3
1. Angle of the substrate	0.5	0.0	0.5
2. Dry weight of the detritus	0.1	1.1	0.7
3. Dry weight of the coarse fraction sediment	1.6	12.3	9.8
4. Dry weight of the sediment	1.3	12.1	0.9
5. Phi kurtosis of the sediment	6.4	10.1	4.0
6. Mean sediment size	3.6	11.0	45.6
7. Mussel bed thickness	2.5	8.3	14.8
8. Pore base of coarse fraction sediment	7.0	27.0	11.5
9. Phi skewness of the sediment	37.4	9.3	8.8
10. Quantity of trapped tar	38.1	1.9	2.7
11. Total residual volume	1.5	6.[illegible]	0.8

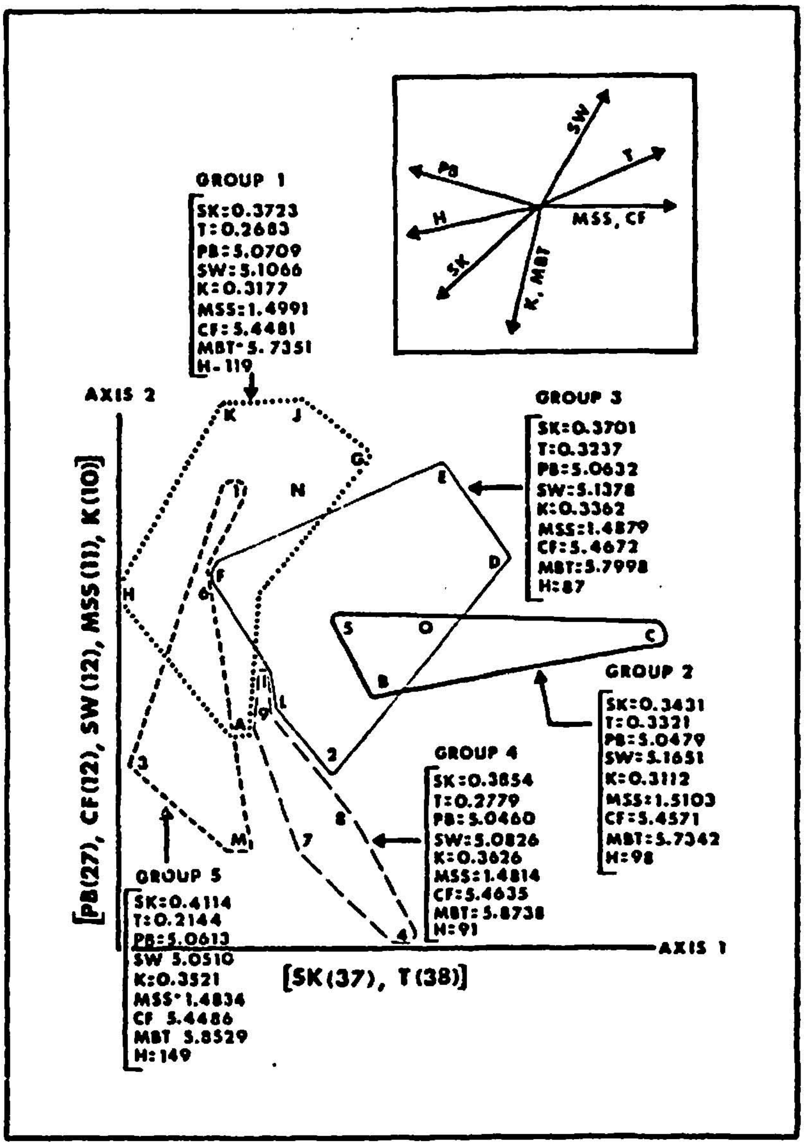

Figure II-7.0-12. Overall discriminant analysis. The importance of each abiotic variable on an axis is indicated by the magnitude of its coefficient of separate determination in parentheses. Arrows in the vector diagram illustrate the direction of increase of each variable mean score.

A = angle of substrate, D = dry weight of detritus, DF = dry weight of coarse fraction sediment, SW = dry weight of sediment, K = phi kurtosis of sediment, MSS = mean sediment size, MBT = mussel bed thickness, PB = pore base of coarse fraction sediment, SK = phi skewness of sediment, T = quantity of trapped tar, RV = total residual volume.

Table II-7.0-6. Group means from overall discriminant analysis.

ABIOTIC CHARACTERISTIC	Group Number from Classification 1	2	3	4	5
1. Angle of the substrate	1.9717	2.0215	2.0091	1.9799	1.9467
2. Dry weight of the detritus	1.2978	1.3302	1.3310	1.3278	1.3137
3. Dry weight of coarse fraction sediment	5.4489	5.4571	5.4672	5.4635	5.4486
4. Dry weight of the sediment	5.1066	5.1651	5.1378	5.0826	5.0510
5. Phi kurtosis of the sediment	0.3177	0.3112	0.3362	0.3626	0.3521
6. Mean sediment size	1.4991	1.5103	1.4879	1.4814	1.4834
7. Mussel bed thickness	5.7351	5.7342	5.7998	5.8738	5.8529
8. Pore base of the coarse fraction sediment	5.0709	5.0479	5.0632	5.0460	5.0613
9. Phi skewness of the sediment	0.3723	0.3431	0.3701	0.3854	0.4114
10. Quantity of trapped tar	0.2683	0.3321	0.3237	0.2779	0.2144
11. Total residual volume	829.6016	842.4314	841.7505	846.9705	840.3330

Table II-7.0-7. Cumulative amount of variance accounted for by each discriminant axis.

Axis	Percent Variance	Cumulative Percent Variance
1	57.4	57.4
2	32.9	89.3
3	8.6	97.9
4	2.1	100.0

Two discriminant axes adequately separated the five site groups resulting from the overall classification analysis for interpretation of group differences (Figure II-7.0-12). However, a small but notable amount of separation was obtained on axis 3. Axis 1 accounted for 57.4 percent of the variance between groups while axes 2 and 3 accounted for 31.9 percent and 8.6 percent, respectively (Table II-7.0-7). The most important variables on the first axis are the quantity of tar (T) and the skewness of the sediment grain-size distribution (PS) (Tables II-7.0-5 and II-7.0-6). The most important variables on the second axis are the quantity of coarse sediment (rock and shell debris, CF), the pore base of the coarse sediment (PB), dry weight of trapped sediment (SW), the mean sediment size (MSS), and the kurtosis of the sediment grain-size distribution. The most important variables on the third axis are the mean sediment grain size (MSS), the mussel bed thickness (MBT) and the pore base of the coarse sediment (PB). The vector diagram (Figure II-7.0-12) indicates that species diversity increases with increased pore base (PB), skewness and kurtosis of the sediment grain-size distribution and an increase in the mussel bed thickness. Species diversity decreased in areas with large quantities of trapped tar and sediments as well as increased mean sediment size.

The most important variables associated with mussel community differences were primarily related to habitat in contrast to food (Figure II-7.0-12). These included quantitative differences in the number of microhabitats provided by the interstitial space (pore base) of the coarse sediment fraction. Coarse sediment fraction constituents included shell fragments and small pebbles (Table II-7.0-8). These materials provided surfaces for attachment of sessile species including the polychaetes Phragmatopoma californica and Chone minuta, the barnacles Balanus glandula, Chthamalus fissus, the coelenterate Anthopleura elegantissima, and many others too numerous to mention here. Coarse sediment material also provides grazing surfaces for several species including the limpets Collisella scabra, C. limatula and C. pelta. The Year-II results (Kanter, 1978) suggested that the highly correlated ($r = 0.89$) coarse sediment fraction and pore base were both associated with higher species diversity. However, the Year-III results in which the correlation between coarse sediment fraction and pore base was still high ($r = 0.91$) (Table II-7.0-9) indicate that only increased pore base is associated with increased species diversity (Figure II-7.0-12). The pore base is manifest in increased numbers of "homes" as a result of increased interstitial space. The "homes", in the form of holes and crevices, also provide spatial separation and shelter for some of the more motile species including the crabs Pachygrapsus crassipes, Petrolisthes cabrilloi and Hemigrapsus nudus, the peanut worm Phascolosoma agassizii, the sea spider Pycnogonum stearnsi and others.

Table II-7.0-8. Coarse fraction composition.

1. Shell de'›ris

   a) broken pieces

   b) empty and worn-away shells (including snails barnacles and mussels)

2. Small rocks and pebbles (greater than 2-mm diameter)

3. Broken and surf-beaten worm encasements

4. Fo..eign objects, e.g. glass and lead fish weights ar· fish line

Table II-7.0-9. Correlation matrix of abiotic characteristics.

ABIOTIC CHARACTERISTIC	1	2	3	4	5	6	7	8	9	10	11
Angle of substrate	1.00										
Dry weight detritus	-0.05	1.00									
Dry weight of coarse sediment	-0.17	0.53	1.00								
Dry weight sediment	0.11	0.58	0.71	1.00							
Kurtosis of sediment	-0.20	0.36	0.18	-0.01	1.00						
Mean sediment size	0.08	0.13	0.11	0.36	-0.35	1.00					
Mussel bed thickness	-0.18	0.44	0.62	0.41	0.70	-0.08	1.00				
Pore base of coarse sediment	-0.21	0.51	-0.91	-0.68	0.18	-0.11	0.62	1.00			
Skewness of sediment	-0.05	0.15	-0.28	-0.40	0.64	-0.69	0.22	-0.18	1.00		
Tar weight	-0.03	0.82	0.47	0.66	0.16	-0.06	0.26	0.52	0.06	1.00	
Total residual volume	0.13	0.22	0.53	0.58	0.36	-0.09	0.74	0.56	0.06	0.29	1.00

Qualitative differences in the character of the sediment trapped within the mussel beds was important in the Year-I and Year-II studies (Straughan and Kanter, 1978; Kanter, 1978). The same degree of importance was again apparent in the Year-III results. Qualitative differences in the mean sediment grain size, and the skewness and kurtosis of the sediment grain-size distributions were important. Higher species diversity was associated with the smaller mean grain size and increased skewness and kurtosis. Initially this would suggest that not only are finer sediments preferred as a habitat by many species but perhaps also as a food source for deposit feeders. Closer examination reveals that the sediment grain sizes fall into the medium to fine-sand size range; such particles are unlikely to have high quantities of organic material associated with them. Their qualitative features, however, directly affect the nature of the sediment microhabitat within the mussel bed and thus the species which inhabit this environment. Many of the polychaetes and molluscs, two of the dominant groups observed in this study, are dependent on the sediment micro-environment. They preferentially inhabit this microcosm and this selectivity is in part governed by the qualitative differences in the sediment (Kanter, 1977).

The thickness of the mussel bed was an important variable related to community differences, with thicker mussel beds generally containing a greater number of species. Mussel bed thickness would logically be intimately tied to the ability of the mussel bed to trap material. However, this hypothesized association did not exist. The vector diagram indicates that thicker mussel beds actually contain less trapped sediments and, further, the quantity of coarse sediments was independent of the mussel bed thickness (indicated by the right angle intersection of mussel bed thickness vector [MBT] with the coarse sediment vector [CF]). We must therefore interpret the affect of mussel bed thickness on the mussel community as providing shelter. Shelter in this instance is generated by the turbulence "damping" affect on wave action. A calmer, less turbulent internal habitat constitutes a sheltered environment for more delicate invertebrates.

The quantity of tar trapped within the studied beds was considered an index of oil exposure. Presence of tar was interpreted as a chemical and physical variable in the internal mussel bed environment. The presence of this substance must be considered a factor with which inhabitants or potential inhabitants must contend. Tar was one of the most important factors associated with community differences and is co-dominant with sediment grain-size skewness on axis 1. Two distinct community features were associated with the high quantities of tar found in the mussel beds primarily from site group 2 (Figure II-7.0-9). The first is illustrated by the vector diagram of Figure II-7.0-12. Those mussel beds which contained the greatest quantities of tar (i.e. Goleta Point and Ventura) contained the lowest number of species. This pattern was also noted during the Year-II study (Kanter, 1978) among collections from Government Point and Goleta

Point. During the Year-I study (Straughan and Kanter, 1978), the observed quantity of tar trapped within the mussel bed was also an important variable. The second quarter discriminant analysis results suggested that lower species diversity was associated with greater quantities of tar (i.e. San Miguel Island mussel bed samples contained the lowest number of species and the highest quantities of tar among the mussel beds compared). Tar was also important in the third quarter discriminant analysis. However, Coal Oil Point mussel beds contained the highest quantities of tar as well as the greatest number of species (74). San Miguel Island samples from this same period contained tar and again supported a low diversity of 55 species. The present findings and those of the previous two years suggest that lower species diversity is associated with the presence of tar. The lone exception to this generalization appears to be the mussel beds at Coal Oil Point. Mytilus californianus from Coal Oil Point were subjected to different doses of crude oil in the laboratory and found to be highly resistent to toxic effects (Kanter, 1971). Perhaps the rest of the community has acclimated like Mytilus to the persistent oil coming ashore from the nearby natural seeps and this may explain the higher diversity at this locality. The tar found in the mussel beds was not characterized as to its origin. The tar may have come from natural oil seeps (Figure II-7.0-13) or other sources. The source may ultimately reflect the chemical nature and also the potential toxic effects.

The second community phenomenon associated with areas containing high quantities of tar is that certain species display their greatest abundance in these mussel beds. For example, many species from species group C exhibit this pattern, including the molluscs Protothaca staminea, Septifer bifurcatus and Mytilus edulis, the polychaetes Eupotamus gracilis, Cerebratulus californiensis, and Typosyllis hyalina. These observations and those discussed previously suggest that while many species cannot live in the presence of tar, some species may adapt or acclimate to thrive in the presence of tar.

7.3.6 Synoptic Comparison of Year I (1975-1976) with Year II (1976-1977) and Year III (1977-1978).

During the first year of the BLM study, the geographic coverage of mussel communities in the Bight was very limited. Only six localities were intensively sampled to document baseline data on community composition and seasonal variability. The extreme complexity of the community in conjunction with site specific differences prompted the recommendation for broader geographic coverage during Year II with less emphasis on seasonal sampling.

Additional impetus for greater geographic sampling of the mussel community came from the results of the classification analysis. The analysis revealed distinct differences between island and mainland

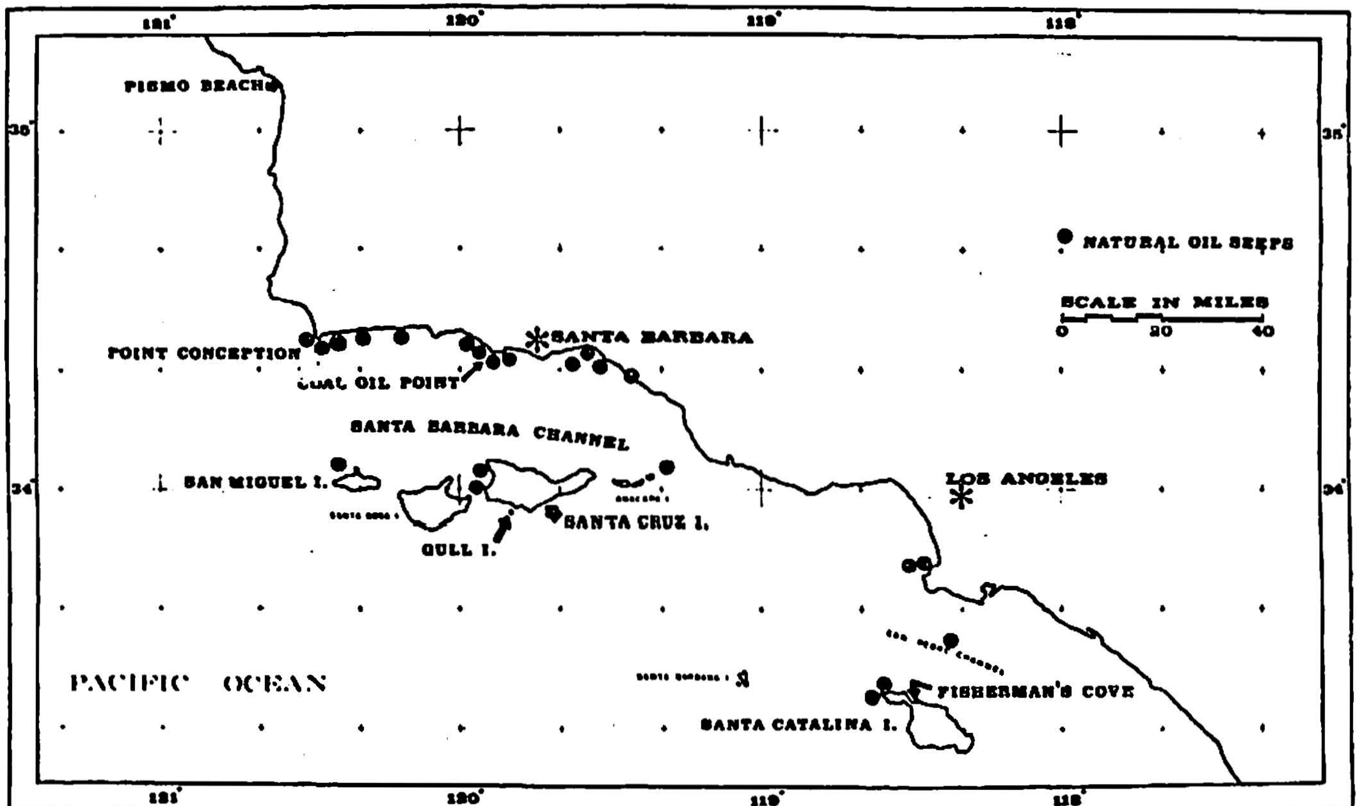

Figure II-7.0-13. Locations of known offshore natural oil seeps.

biota. The factors responsible for these differences were not immediately clear and were open to much speculation. Among the possible explanations for the community differences was the physical separation of the islands from the mainland, thus potentially isolating the island mussel beds. The differences could also reflect the affect that water masses and currents which bathe the islands have on the distribution of planktonic larval recruits.

The Year-II and Year-III programs sampled successively more mussel beds covering a greater geographic area within the Southern California Bight. The results of community similarity analysis allowed finer delineation of biogeographic patterns of species distributions. The "island-mainland" pattern from Year I was better defined as a "north-south" pattern reflecting the influence of cold and warm water provinces of species. The mussel communities from various geographic areas including island and mainland localities were included in both the "northern" and "southern" groups. Further, the Year-III results suggest that opposite sides of islands support different mussel communities which may consist of either warm or cold water assemblages. The Year-II and Year-III data suggest that between-habitat features (e.g. currents and water masses which carry planktonic larvae) are responsible for the observed species biogeographic distribution patterns.

The Year-II and Year-III programs also examined the community differences associated with intertidal height extremes. The results from both years indicate that some mussel communities do exhibit distinct compositional differences within a localized mussel bed. Moreover, these differences are maintained through time. Other mussel beds appear to be extremely heterogeneous, and samples from different intertidal heights display no consistent pattern of similarity or dissimilarity.

The results of all three years' studies suggest that local habitat features were also correlated with community differences. These features reflected qualitative and quantitative differences in the microhabitat provided by the mussel beds. Habitat features, including sediment amounts, grain-size distribution and the quantity of coarse sediment debris and its associated interstitial space, were found to be most important.

The presence of tar in the mussel beds was a significant discriminant variable in all three years. Generally, community diversity was lower when quantities of tar were high. In addition, certain species occurred in higher abundance when tar was present. The origin and source materials from which the tars came may be quite variable. Thus, any interpretation should be supplemented by additional chemical information.

7.4 RECOMMENDATIONS FOR FUTURE RESEARCH RELATED TO OCS OIL LEASES.

Baseline data collection is a necessary prerequisite of "effects" studies. Obviously changes which may result from offshore oil exploration, construction and production can only be assessed when adequate background information exists. This goal has been satisfactorily reached by the completion of the Year-III mussel community study. A logical next step in the investigative process is to define vulnerability and potential impacts on the mussel community resulting from spilled oil. The mussel community has previously been overlooked following major spills; yet, as we have demonstrated, a tremendously rich community is harbored within the mussel bed.

The following recommendations are made to provide supplemental data needed for predicting potential impacts of oil pollution on the mussel community:

- Laboratory bioassays testing crude oil effects on selected ubiquitous species which represent the major phyla comprising the mussel community.

- Laboratory bioassays on the same species selected for oil studies testing the effects of various oil clean up techniques including chemical dispersants and physical removal by steam.

7.5 SUMMARY

The communities associated with Mytilus californianus (mussel) beds from 20 geographic sites in southern California were examined. The study areas included six mainland sites — Government Point, Goleta Point, Ventura, Corona del Mar, Carlsbad and San Diego, and two sites on opposite sides of seven offshore islands — San Miguel Island, Santa Rosa Island, Santa Cruz Island, Anacapa Island, San Nicolas Island, Santa Catalina Island and San Clemente Island. The mussel communities from all areas contributed to the master species list which now encompasses conservatively, 610 species of animals and 141 species of algae. The most diverse collection came from Cat Rock, Anacapa Island where the mussel beds supported 174 species of invertebrates. The lowest diversity was recorded for mussel beds from Ben Weston, Santa Catalina Island which contained 46 species. In general, the island mussel beds supported a greater diversity of both animals and plants. Mussel community samples were collected from upper and lower intertidal areas occupied by the mussel beds within a locality. Community differences in both composition and abundance were associated with these collections.

Overall, community similarity analysis revealed five major patterns which corresponded to characteristic species assemblages occupying the mussel beds from the various geographic areas. The patterns

included: (1) clusters of localities which display a north-south geographic pattern with respect to the similarity of their respective mussel communities, (2) a separation of selected island and mainland communities because of dissimilarities in their species composition, (3) differences between mussel communities on opposite sides of the offshore islands, (4) clusters of species whose highest abundances characterize selected localities, (5) species groups ubiquitous to all mussel beds examined. The results of the community analysis further suggest that predictions can be made delineating the probable mussel community inhabitants of areas not sampled. The species distribution patterns observed appear to correspond in part to the influence of currents and water masses which bear planktonic larvae and impinge on selected localities.

The most important mussel bed features associated with community differences were quantitative and qualitative differences in the potential microhabitats. Those features associated with greater species diversity include the pore base of coarse fraction shell and rock debris, skewness and kurtosis of the sediment grain-size distributions and mussel bed thickness. Those features associated with lower species diversity included the quantity of tar, and rock and shell debris trapped within the mussel bed.

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